A MECHANIZED DEVICE FOR PACKING SOIL COLUMNS

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A MECHANIZED DEVICE FOR PACKING SOIL COLUMNS

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Upon initiation of experiments concerning the flow of water in unsaturated soils at the U.S. Water Conservation Laboratory, the need for a rapid, reproducible means of packing soil columns having uniform bulk density became evident. The necessity of packing soils to a uniform bulk density and the desirability of obtaining replicate samples for use in physical experiments on soils was stressed by Buckingham (2)[2] in 1907. In recent work on soil-water diffusivity, discrepancies in data have been attributed to nonuniform packing (1, 3). Nielsen et al. (5) demonstrated that uniform density is the key to precise soil-water diffusivity measurements.

A common method of packing soil columns is to tamp small, weighed increments of soil into the column. This, in addition to being tedious and time consuming, frequently results in layering and inhomogeneous particle size distribution. Vibration techniques (6, 7) have been shown to minimize layering. Utilizing a tremie to introduce the soil into the column (4) has aided in reducing particle size separation. Inherent in these methods is the inability to obtain replicate samples. The device described here utilizes a motorized tremie and vibrator block in combination. This device packs columns with soil to a uniform bulk density within the column, reproducibly and rapidly.

Description Of Packer

The packer consists of three main parts: A motorized tremie, a vibrator block assembly, and an angle iron framework uniting the two. Figure 1 shows the entire assembly and figure 2, A and B, the details of component parts. Exact dimensions of the device are dependent upon the length and area of the column to be packed and may vary with individual needs. The following description is pertinent to the present device, but the basic principles should be applicable to devices of other dimensions.

The tremie motor (A) is connected to the tremie (detail 2) by a 36-inch long, 3/8-24 threaded rod (D).[3] The tremie assembly is held in a vertical position by a split nut (detail 1) in the centering plate (E), a shaft guide (F) located about 6 inches below the centering plate, and 2 aluminum rods (C) which guide the tremie motor as it ascends. The tremie motor mounting plate (B) connects the motor to the aluminum guide rods and also holds an electrical outlet. The outlet is serviced by a 2-conductor helical electrical cord. The tremie motor wires plug into the outlet. This arrangement facilitates changing motors. The split nut (detail 1) provides the means whereby the motor "lifts" itself and the tremie as it rotates. The nut is tapered to fit snugly in the centering plate (E) and to facilitate removal when the tremie assembly is to be lowered. Slotted holes are milled in the centering plate to serve as an adjustment to align the tremie assembly with the column, the latter being held on the block. It is important that the tremie is not rigidly attached to the drive shaft. The tremie must turn when the motor turns,

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[2] Italic numbers in parentheses refer to Literature Cited, at end of this publication.

[3] The tremie motors are small gear motors, numbers 4K808, 5K204-5K207, W. W. Grainger Inc., Phoenix, Arizona.

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but the connection must be such that the tremie will not bind in the column if the tremie and column are not perfectly aligned. This is accomplished by drilling the hole at the bottom of the threaded rod (D) sufficiently large that the bolt holding the tremie funnel holder (T) fits loosely in the rod.

The tremie (shown in detail 2, figure 2, B) is a stainless steel funnel (S) connected to a 1/2-inch o.d. lucite tube (U). The tube is offset from center such that when rotated the outside edge of the tube is the axis of rotation. Affixed at the bottom end of the tube is a lucite spacer (V), which serves to keep the tube aligned in the column. The outlet from the spacer is vee-shaped, with the point of the vee toward the center of the spacer.

The vibrator block is constructed of jig and fixture aluminum (O) 1-3/4 by 5-1/2 by 18 inches. A vee notch is cut in the center, three-fourths of an inch deep to serve as a receptacle for the column. Fastened to the four long edges of the block are 3/4- by 3/4- by 1/8-inch stainless steel angles (P) which are used to prevent deformation of the block when vibrating against the adjusting bolts (K). The adjusting bolts protrude through the frame from four sides and hold the vibrator block vertical and in such a position that the tremie can be freely lowered into the column. The clearance between the bolts and the block is 0.004 to 0.005 inch depending upon the amount of vibration desired. Hardened steel bolts are recommended to minimize wear which would change the clearance and hence, the amount of vibration.

Vibration is provided by a motor with a weight offset on the shaft (R). The vibrator motor is of the same type used by furniture manufacturers to make vibrating chairs.[4]

The vibrator block is supported at the bottom by a brass rod (N) fastened to the packer base. The block and the rod are separated with a #0 rubber stopper. The stopper is essential because it enhances vertical vibrations of the block.

The lucite column is clamped in the vee notch of the block by a brass angle, called the column clamp (figure 2, B), bolted to the block on the top and the bottom (Q). Weights are added to the angle at several points to break up nodes of vibration. The amount of necessary weights and their location can be found by trial. When the column is clamped to the block, it is essential that the column be held with the same pressure each time, otherwise nonuniformity within the column may result and reproducibility may be affected. This is accomplished by placing a spacer of proper length on bolts (Q). The proper length is determined by trial.

Figure 1.--The mechanized soil column packer.

The framework (H) is constructed from 1-1/2 by 1-1/2 by 1/8-inch angle iron welded and bolted together (I, J). The framework provides a base and unites the tremie assembly and vibrator block. The base (L) has bolts (M) for leveling the framework. Two 35-pound lead weights (W), one on the centering plate (E) and one on the base (L), are used to dampen vibrations of the frame when the block vibrates.

[4]Number 7X006, W. W. Grainger Inc., Phoenix, Ariz.

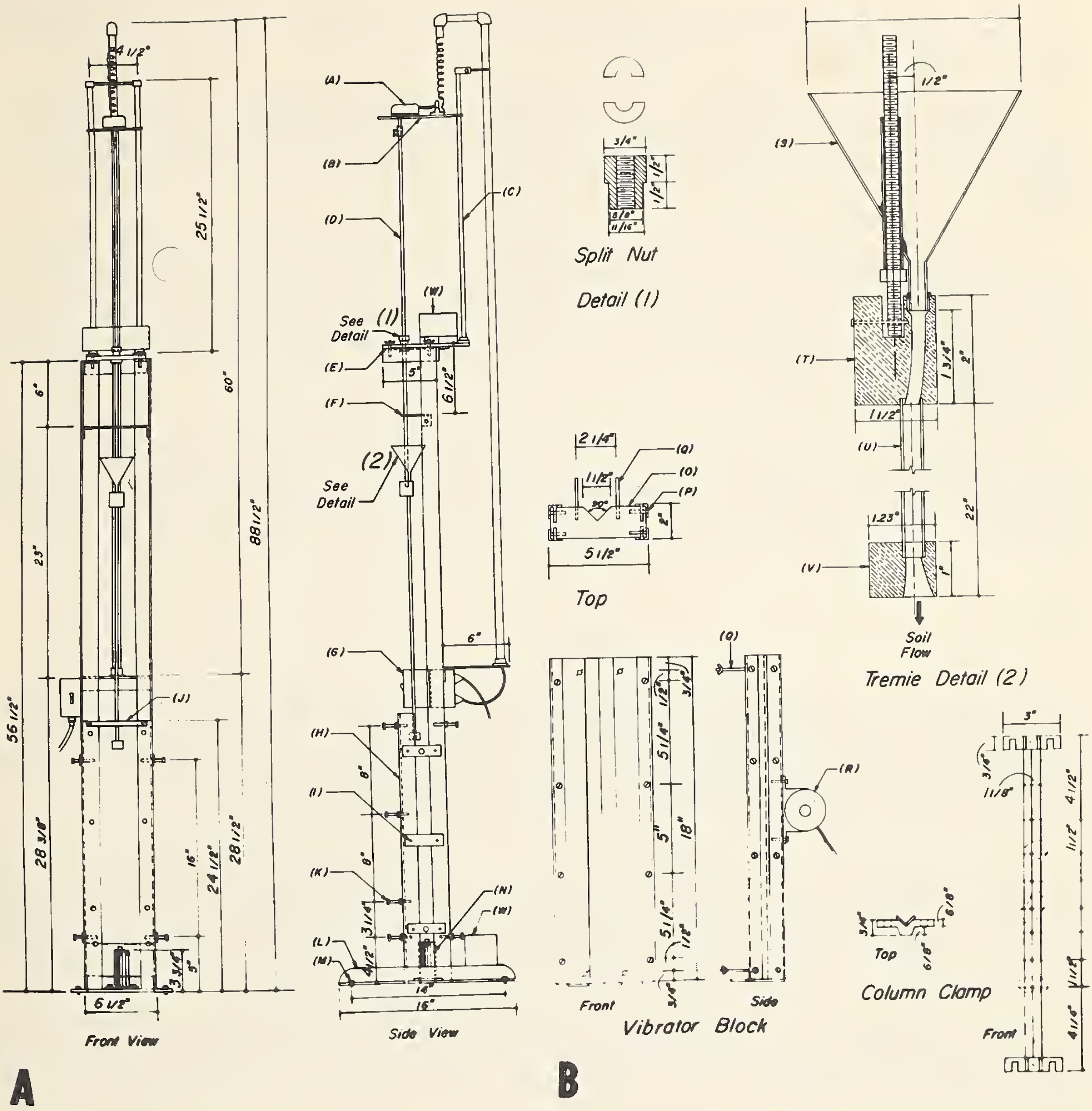

Figure 2.--A, Overall details of packer; B, expanded details of component parts.

Operations

The column is made from 3.18 cm. i.d. lucite tubing cut in 1-cm. sections. The 1-cm. sections are taped together with masking tape to make a 45-cm. long column. The column is placed on the vibrator block, clamped to the block with the column clamp, and the tremie lowered into the column. The masking tape should not touch either the block or the clamp. The tremie is filled with soil and the vibrator and tremie drive motors are turned on simultaneously with switch (G). The tremie funnel is kept full of soil during the operation. The soil is compacted by vibration as it is deposited in a helical pattern by the tremie. For best results the soil should be essentially air-dry. The soil must be well mixed before placing in the funnel.

When initially filling the tremie, unavoidable separation of particles occurs. This causes nonuniform density in the first few centimeters of the column. Also, near the top of the column

extraneous vibrations of the tremie may cause some nonuniformity. For this reason we use the center 30 centimeters of the column for our experiments.

The tremie drive motor can easily be changed to one of another speed. We use motors with speeds of 5, 8, 18, 24, and 35 r.p.m. With the 35 r.p.m. motor, a column can be packed in 11 minutes. The degree of vibration from a vibrator motor can be controlled by adjusting the amount of offset weight on the shaft. We use three motors, each with a different, fixed, offset weight.

Low bulk densities can be obtained by using a fast tremie motor and a low-vibration vibrator motor. Conversely, higher bulk densities can be obtained using a slow tremie motor and a high-vibration vibrator motor. Thus, various combinations of tremie and vibrator motors can be used to obtain a range of bulk densities. If no adjustment is made on the bolts supporting the vibrator block and well-mixed soil from the same lot is used, the bulk density of a particular soil resulting from a given set of tremie and vibrator motors can be reproduced, when desired, by using the given set.

The clearance between the bolts and the block should be checked periodically. When packing a column it is possible that some soil grains may get between the adjustment bolts and the block. This will change the amount of vibration and will result in nonreproducible packing. A hose connected to a compressed air line is used to blow soil particles from the packer. We find it necessary to do this each time before packing a column.

Results

Evidence of reproducibility of this device is given in table 1. Three soils were packed using three different tremie-vibrator motor combinations. Combination 1 was 35 r.p.m. tremie motor--low vibrator. Combination 2 was 35 r.p.m. tremie motor--medium vibrator. Combination 3 was 25 r.p.m. tremie motor--heavy vibrator. Each bulk density given in table 1 is the mean of five samples. These results show that reproducibility of this device is excellent.

Evidence of uniformity throughout the 30-cm. column is indirect in that bulk densities were calculated from water content data. Soil columns were packed, equilibrated with water at -2 mb. pressure, sectioned at each centimeter, and the moisture content determined gravimetrically. The overall density and the mean water content of each column were used to estimate the volume of entrapped air. Bulk densities were calculated for each 1-cm. section, assuming the fraction of entrapped air to be equal in all sections. Data for five columns are shown in table 2.

The small standard deviations show that the objective of uniformity was achieved. All five columns exhibited essentially the same amount of deviation. The coefficients of variation indicate that for different soils and different densities, the same relative variation of uniformity within columns can be expected.

Statistical analysis indicated that the mean bulk densities of 1.519 and 1.523 were not significantly different at the 0.001 level, but that the mean bulk densities 1.435 and 1.453 were significantly different at the 0.001 level. The columns having bulk densities of 1.519 and 1.523 were packed as duplicates whereas the columns having densities of 1.435 and 1.453 were packed at different packer settings.

Nielsen et al. (5) used a comparison of the rates of advance of the wetting front for different columns packed to the same bulk density as a means of checking the uniformity and reproducibility of their method of packing. Figure 3 shows the rate of advance of the wetting front as a function of the square root of time for six columns of Adelanto loam. Columns were packed at three densities, each density in duplicate. At each density one column was allowed to wet to 18 centimeters and one to 27 centimeters. The 18-cm. columns are designated with "x" and the 27-cm. columns with "●." It can be seen that for each density, the duplicates have identical lines. Using Nielsen's criteria, one can state that at each density the columns were duplicates and were of uniform density.

TABLE 1.--Reproducibility of bulk density.

Soil	Motor combination	Mean bulk density	Standard deviation	Coefficient of variation
		$g. cm.^{-3}$		
Adelanto loam	1	1.430	0.004	0.003
	2	1.475	.004	.002
	3	1.547	.003	.002
Pachappa loam	1	1.354	.002	.002
	2	1.413	.002	.001
	3	1.479	.005	.004
50-500μ sand	1	1.544	.003	.002
	2	1.563	.004	.003
	3	1.602	.003	.002

TABLE 2.--Uniformity of bulk density of 30 cm. columns.

Soil	Mean bulk density	Standard deviation	Coefficient of variation
	$g. cm.^{-3}$		
Pachappa	1.275	0.005	0.004
Adelanto	1.435	.006	.004
Adelanto	1.453	.006	.004
Adelanto	1.519	.006	.004
Adelanto	1.523	.006	.004

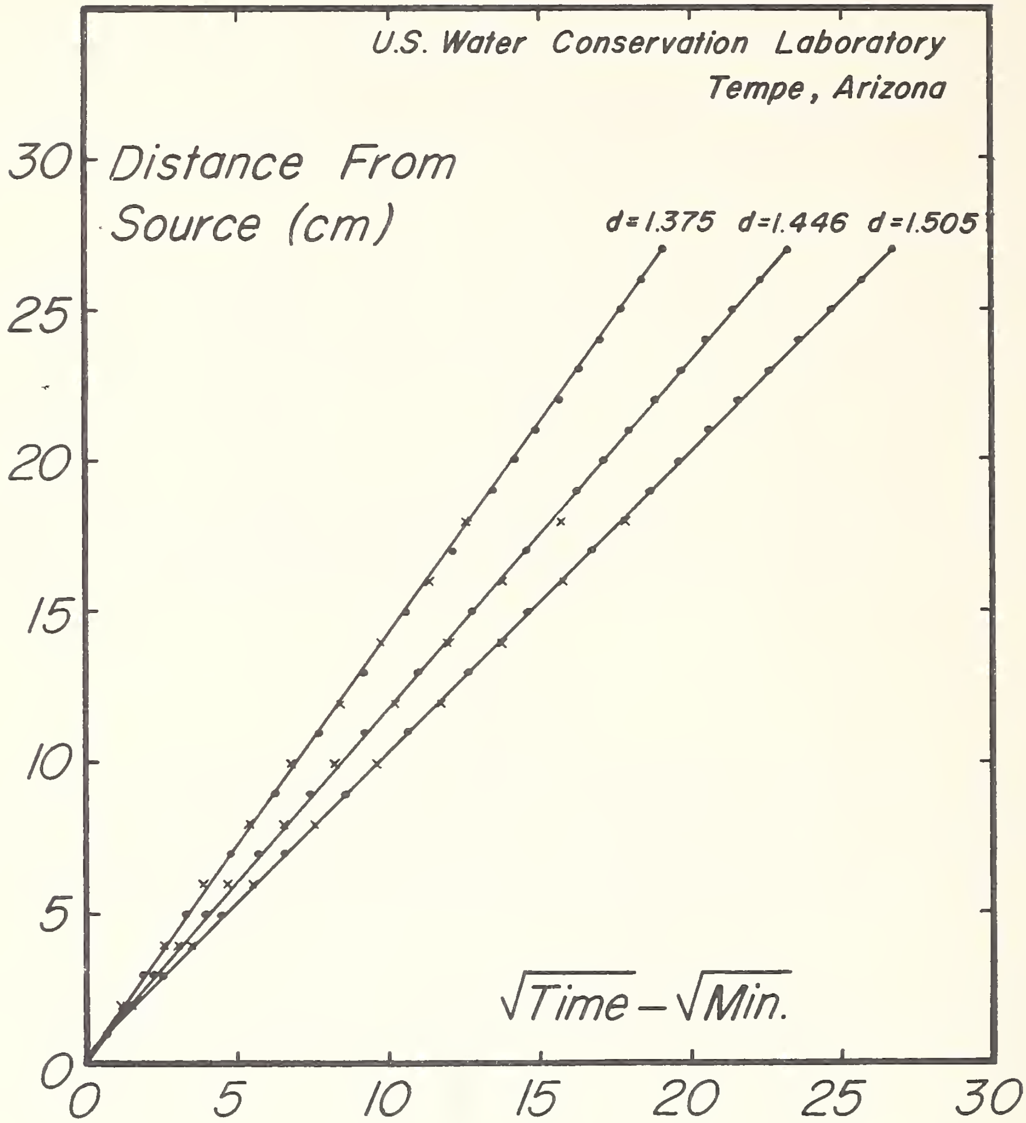

Figure 3.--Distance to the wetting front versus the square root of time for 6 horizontal columns of Adelanto loam packed to 3 bulk densities, each density in duplicate.

Figure 4 shows the type of water content distribution data that can be obtained from soil columns packed with this device. These data were obtained in order to measure the soil-water diffusivity of a sample of Adelanto loam. It is evident that the data are sufficiently precise that a smooth curve can easily be drawn through the data points.

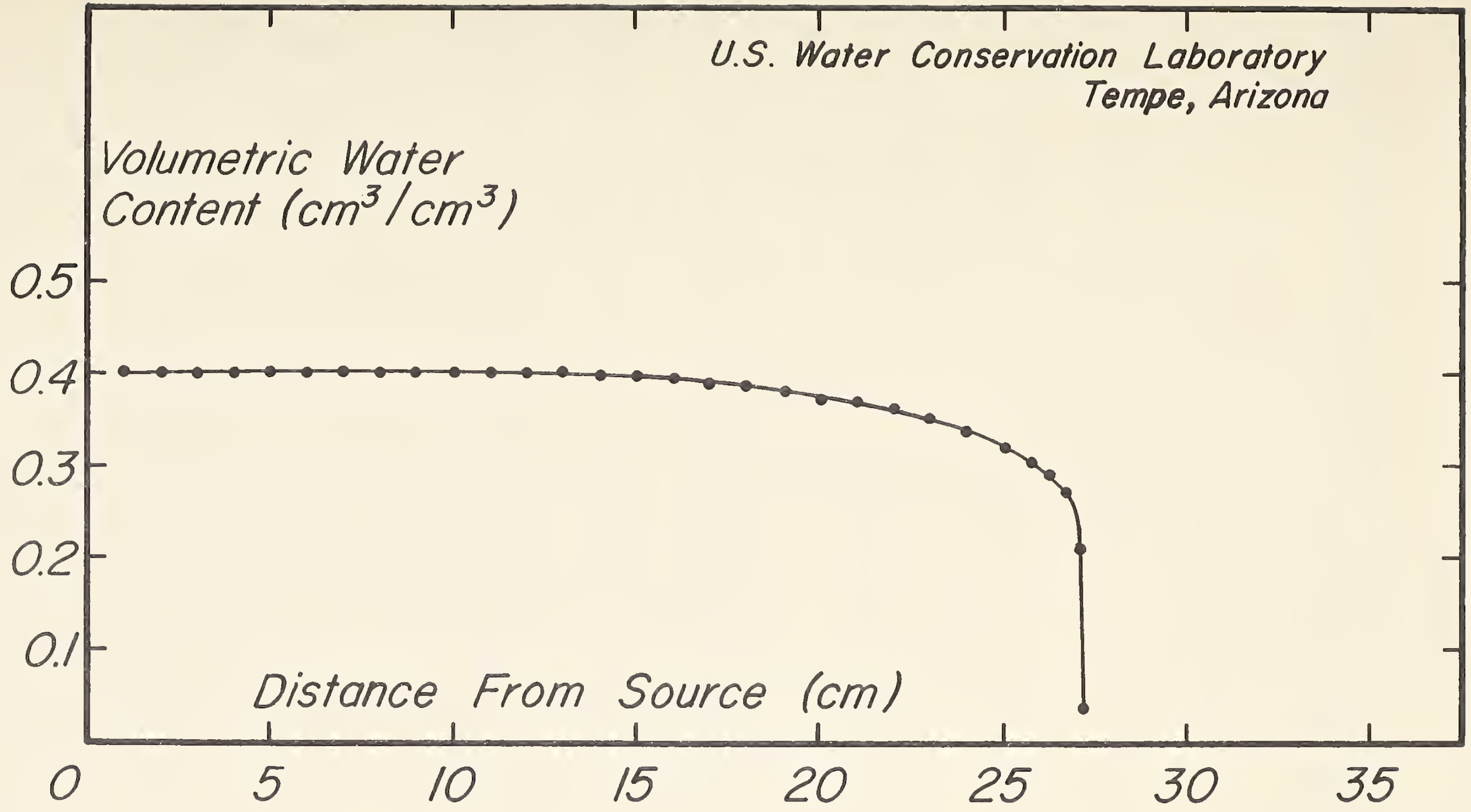

Figure 4.--Water content distribution, Adelanto loam, bulk density 1.446 g. cm.$^{-3}$.

Summary

A device is described that utilizes a motorized tremie and a vibrator block in combination to pack columns with soil to a uniform bulk density, rapidly and reproducibly. Data are presented which show the degree of uniformity and reproducibility.

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